

UPPER PACIFIC MILLS BRIDGE  
E  
(MOSLEY TRUSS BRIDGE)  
Spanning Merrimack River  
Lawrence  
Essex County  
Massachusetts

HAER NO. MA-72

HAER  
MASS,  
5-LAWR,  
6 -

PHOTOGRAPHS

ADDENDUM  
FOLLOWS...

Historic American Engineering Record  
National Park Service  
Department of the Interior  
Washington, D.C. 20013-7127

Addendum to  
Upper Pacific Mills Bridge (Moseley Truss Bridge)  
Originally spanning the North Canal at the Upper  
Pacific Mills in Lawrence; (Presently in storage  
at Merrimack College in North Andover)  
Essex County  
Massachusetts

HAER No. MA-72

HAER  
MASS,  
5-LAWR.  
6-

PHOTOGRAPHS  
REDUCED COPIES OF MEASURED DRAWINGS  
WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record  
National Park Service  
Department of the Interior  
Washington, DC 20013-7127

HISTORIC AMERICAN ENGINEERING RECORD

UPPER PACIFIC MILLS BRIDGE  
HAER No. MA-72

HAER  
MASS.  
S-LAWR,  
6-

**Location:** Originally spanning the North Canal on Canal Street between Franklin and Hampshire Streets, Lawrence, Essex County, Massachusetts; Presently in storage at Merrimack College, North Andover, Massachusetts

**Date of Construction:** 1864

**Type:** Wrought-iron tubular tied arch bridge

**Designer:** Thomas W. H. Moseley, Cincinnati, Ohio

**Builder:** Moseley Iron Building Works, Boston, Massachusetts

**Previous Use:** One-lane vehicular bridge

**Present Use:** Moved from original location; restoration in progress

**Significance:** The Upper Pacific Mills Bridge, built to carry workers and supplies to the mills, is one of only three or four known surviving examples of Thomas Moseley's wrought-iron tubular arch bridge. First built in 1855, Moseley's bridge designs evolved over a period of approximately twenty years and were the subject of several U.S. patents. Moseley is generally credited with introducing the riveted wrought-iron tubular arch to the American market. The "tubular" arch is actually a hollow triangle in cross-section, fabricated from iron boiler plate. The prominent counterarches, beneath the main arch of the bridge, were an attempt to prevent excessive deflection of the arch under asymmetrical deck loading. The Upper Pacific Mills Bridge was one of three tubular arch bridges that Moseley built at Lawrence. It is the oldest extant iron bridge in Massachusetts and one of the oldest riveted wrought-iron bridges in the United States. The bridge was rescued from demolition in 1989 and rehabilitated by students at Merrimack College, under the direction of Francis E. Griggs, Jr., Professor of Civil Engineering. The intent is to return the bridge to a site on the North Canal as a footbridge.

**Project Information:** Documentation of the Upper Pacific Mills Bridge began in the summer of 1990 as part of the Massachusetts Historic Bridge Recording Project, and continued in the summer of 1991 as part of the Cast & Wrought Iron Bridges Recording Project, under the auspices of the Historic American Engineering Record (HAER), a division of the National Park Service. Historical information recorded by Francis E. Griggs, Jr. Edited and transmitted by Lola Bennett, HAER Historian.

## DESCRIPTION

The Upper Pacific Mills Bridge is a 96-foot, single-span, riveted wrought-iron Moseley tubular arch bridge with iron auspenders and counterarches. The hollow upper chord is an isosceles triangle in cross-section, and is comprised of riveted wrought-iron boilerplate. At various intervals along its length, the sections of the tube are fastened together with rivets and splice plates. (During the bridge's rehabilitation, many of the original rivets were replaced with bolts.) The upper chord, a segmental arch in elevation, rises to a height of approximately 10' above the level of the lower chord at the center of the truss. The lower chord is comprised of paired 1"x3" iron bars, bolted together with spliceplates. At either end of the truss, the ends of the lower chord are forge-welded to shoe stops, on top of which is a ¼" shoe plate to which the upper chord is riveted. The bridge is approximately 18' wide.

Each truss is divided into five panels, with the upper and lower chords connected by a series of iron rods and straps. The rods (2-3/16" diameter) are paired and located at the panel points, where they are secured to the transverse floor beams by means of a strap and plate connection. At the upper chord, the pairs of rods are secured by means of a bracket attached to the underside of the upper chord. The rods straddle the angles of the counterarches, and are connected at their midpoint with a 2½"x1'-4½" cross-strap. A single ¾" rod is attached to the upper and lower chords at the center of the truss. The suspension straps (2-5/16") are fastened vertically and at even intervals along the length of the truss, eight within each panel. They are suspended from iron hangers which are riveted into the upper seam of the top chord, and pass through a slot in the bottom of the upper chord. The straps pass between the angles of the counterarch and the lower chord bars, and are secured beneath the lower chord by means of a stirrup and hex nut.

The prominent counterarches, composed of paired wrought-iron angles (2½"x3½"x¾"), extend beneath the main arch, from the footings to the crown. The counterarches are fastened to the upper chord at either end and the midpoint by means of riveted brackets on the underside of the chord. These counterarches were an attempt to prevent excessive deflection of the arch under asymmetrical loading conditions.

The floor system--now removed--originally consisted of: four continuous, triangular-section transverse floor beams, which were fastened to the lower chord by means of a bent rod, stirrup and hex nut; timber stringers resting on top of the floor beams; and wooden decking on top of the stringers. Originally, the floor beams were cantilevered out beyond the truss to support sidewalks on both sides of the bridge.

## HISTORICAL CONTEXT

The Great Stone Dam across the Merrimack River, completed in 1848, made possible the creation of the new industrial city of Lawrence, Massachusetts. This new city was similar to Lowell, built twenty years earlier just upstream. Both cities were sited near rapids so as to tap the abundant water power of the Merrimack River for textile mills. The five-foot drop at Lawrence, however, required a high dam to provide water at the elevation needed to power

the proposed mills. This dam was constructed between 1845 and 1848 under the supervision of Charles Storrow, Chief Engineer for the Essex Company (the organization which built the water power system and owned all of the land in what is now the city of Lawrence). Considered an engineering marvel of its day, the dam was made of massive granite blocks, and measured 33' high and 1600' long. The North Canal, over a mile in length, was constructed simultaneously with the dam to supply water to the mills. (See Figure 1.)

Incorporated in 1853, the Upper Pacific Mills were the largest of the original mills in Lawrence. Financed and managed by Abbott Lawrence, the owner of several mills at Lowell, the Upper Pacific Mills were built on the island between the Merrimack River and the North Canal. Water from the canal flowed through penstocks to turn a turbine, which distributed power throughout the mills by means of belts and iron shafts. By 1860, the Pacific Mills could boast of being one of the largest producers of worsted and cotton goods in the country.

As the mills became established at Lawrence, the companies built housing for the workforce around the city's industrial core. Bridges were an immediate necessity to provide access for both materials and workers. Most of the early bridges were simple timber spans, which often needed replacement within a few years. In the 1860s, the Moseley Iron Building Works of Boston erected three wrought-iron tubular arch bridges at Lawrence: the Munroe Paper Company Bridge, near the intersection of Merrimack Street and South Broadway (1867-1970s); the Washington Mills Canal Bridge, near the intersection of Canal and Mill Streets (1863-1886); and the Upper Pacific Mills Bridge, between Franklin and Hampshire Streets (1864-). (See Figure 2.) Of the three Moseley trusses, only the Upper Pacific Mills Bridge has survived.

The Upper Pacific Mills Bridge was built across the North Canal in 1864, replacing a wooden bridge which had become unsafe. Today, this bridge is the oldest extant iron bridge in Massachusetts, and one of the oldest wrought-iron bridges in the United States. It is one of only three or four known surviving examples of a Moseley truss in the nation. (See Figure 3.) The Great Stone Dam is still standing, as are many of the brick mills built in the 1850s and 60s. Nearby, the mills and canals of the city of Lowell attract large numbers of visitors each year.

As one of the oldest surviving iron bridges in the country, the Upper Pacific Mills Bridge is significant in its own right, but it becomes even more significant when viewed within the context of the industrial development of the late-nineteenth century. At about the same time that the textile mills were expanding, the first bridge building companies were being organized. Mass-production and standardization of parts were adopted by both industries to increase both productivity and profits. In the bridge manufactories, bridge sections were fabricated prior to being shipped to the site. The bridge companies published catalogs of their work, and bridges were ordered "off the shelf," in much the same way that cloth was ordered from the textile mills. Thus, two very different artifacts--the cotton cloth produced in the textile mills and the bridges produced in the bridge manufactories--share the common link of mass-production. The significance of the Upper Pacific Mills Bridge, therefore, takes on an added dimension within its original historical and geographical context.

THOMAS W. H. MOSELEY

Thomas William Henry Harrison Moseley was born in Mt. Sterling, Kentucky on November 28, 1813. His first exposure to the iron business came when he worked at Union Furnace, the first iron furnace built on the Ohio River at Irontown, Ohio. This opportunity gave Moseley an introduction to iron-making and allowed him to see iron put to many uses. He knew, for example, of Captain Delafield's cast-iron arch bridge on the National Road at Brownsville, Pennsylvania, built in 1839--the first iron bridge built in the United States. Moseley had, in fact, superintended the weighing and shipping of the elliptical cast-iron tubes used in the bridge. For the rest of his life, he continued to be fascinated by the production and uses of iron, writing in 1863:

It may be confidently asserted that, except the Gospel, Iron has been the most potent of all agents in the civilization of mankind. It cannot but be observed, that, exactly in proportion as communities, tribes, and nations have learned the uses of this bounteous gift of the Creator, they have advanced in science, in culture, and in Christianity.<sup>1</sup>

In 1841, Moseley took up civil engineering, specializing in roadway layout and bridges. He noted that bridges were his greatest challenge, saying:

Almost every individual, who as its engineer, has made ten miles of road, has at one time or another conceived a new plan of bridge; for of all the troubles which beset an engineer in constructing and operating a road, its Bridging is the greatest.

Moseley was first exposed to wooden bridges built by Lewis Wernwag and Theodore Burr, who both used arches extensively. He apparently read the technical journals of the day, as he was familiar with Robert Stephenson's Britannia Bridge made of wrought-iron plates riveted together into a rectangular tube, which he referred to as "a gigantic monument to the brute force of labor and money." Moseley also knew of Thomas Telford's iron arch bridges in England, Scotland and Wales. He also may have been influenced by Frederick Harbach's iron truss which used wrought iron plates riveted together for the lower chord. Harbach built several of these bridges for the Cleveland, Columbus and Cincinnati Railroad between 1848 and 1850. Moseley was working in that area at the time and could have seen some of Harbach's trusses, where he may have picked up on the riveted wrought-iron tube idea. While Harbach's trusses were based on the Howe form, however, Moseley believed that "no bridge should be considered safe without the arch." Moseley may also have been aware of the designs of several other bridge builders, such as Brunel, Whipple, and W.C. Harrison, but there is no documentation of how his ideas were derived. Eventually, however, Moseley came up with a design for a riveted wrought-iron tied arch.

In 1854 Moseley built his first tubular tied arch bridge across Bank Lick Creek on the Bank Lick Turnpike near Covington, Kentucky. This bridge, a

60-foot span, was constructed using only hand tools, and cost \$2100. Four years later, Moseley received a patent and set up a factory in Cincinnati to manufacture his bridges. He went on to build over sixty of these bridges, including seventeen in Ohio and eight in Kentucky. One of his bridges was a 59-foot aqueduct on the Ohio & Erie Canal near Akron, Ohio, built in 1859. This structure was sized to carry a trough of water 22' wide and 4' deep.

Moseley was planning to move his business to Richmond, Virginia, in 1861, as he had been offered the contract to build all of the bridges across the James River and Kanawaha Canal. However, the beginning of the Civil War forced him to cancel this plan and to shut down business in Cincinnati. He then received an invitation, with a promise of financing, to move his operation to New England, and shortly thereafter, Moseley established his business at 31 Washington Street in Boston. His new plant, housing all of his specially-designed equipment, was completed in October 1861, and Moseley began to successfully build iron bridges and buildings throughout New England. (See Figure 4.)

The company's 1863 prospectus gives some indication of just how well the company was doing. In it, Moseley indicated that he was looking for someone to set up a rolling mill near his manufactory, so that he would have a more reliable source of plate stock in the sizes that he needed for his bridges and roof structures. He stated that "no one business, well attended to, pays any better than this; while in vitality and variety it excels almost any other." He also indicated that the company had received requests from the British Provinces, the West Indies and South America, convincing Moseley that "the field is almost limitless for energy and enterprise."

By 1870, Moseley had obtained three more bridge patents, all of which were variations on his original patent. A company pamphlet from 1870 stated that Moseley had built over two hundred bridges, including three bridges at Lawrence, in the nine years since his company relocated in Boston. The Upper Pacific Mills Bridge was built in 1864 at the height of the Civil War, indicating that Moseley had a source of iron which was unusual as the war effort was taking most of the resources of both the North and the South.

In 1871, Moseley sold his interest in the plant to the New England Iron Company. A few years later he moved to Scranton, Pennsylvania, where he "lived in style" until his death on March 10, 1880.<sup>3</sup>

#### THE MOSELEY TRUSS

First built in 1855, Moseley's bridge designs evolved over a period of approximately twenty years and were the subject of several U.S. patents. (See Appendix.) The design of the Upper Pacific Mills Bridge is based on the first two patents.<sup>4</sup> The first patent, issued February 3, 1857, described an iron bridge having hollow arches whose transverse section was an isosceles triangle. Moseley felt that these arches would "[present] at once the combined features of extraordinary strength and lightness." The bridge was fabricated entirely of wrought iron plate, bars and strap stock at a time when Squire Whipple, the premier iron bridge builder of his day, was constructing bowstring trusses (patented in 1841) made of cast and wrought iron.

In his 1863 prospectus entitled Iron: New Enterprise in its Manufacture and Applications to Building, Moseley stated, "In 1859, a radical improvement

was made in the bridge, greatly increasing its strength and stiffness." This improvement was the addition of the counterarches and a short piece of iron running from the loop over the top chord to the counterarch. Moseley described this bridge as follows:

It is the result of long experiments to devise a structure, which, for moderate spans, should combine the utmost economy with strength; and, at the same time, satisfy those who prefer a firm and less elastic Bridge than the other. In rigidity it approaches a stone bridge; while, even in New England, its cost is not far from that of wood. For railway and common travel it is altogether the most economical mode of construction yet invented.<sup>5</sup>

The Moseley Truss is better described as a stiffened arch than a truss. It was one of the first bridges to be made entirely of wrought iron. The upper curved members are made of triangular cross-sections. A curious aspect of the structure is the function of the reversed-curve members beneath each half of the arch, whose function Moseley stated was "to counteract undue deflection." (See Figure 5.) Under full loading conditions the structure functions as a classic rigid arch in which the depth of the structure varies directly with the external bending moment present. Under partial loading conditions, however, the structure is sensitive to shape changes and localized bending, which can cause severe bending and eventual collapse. Analysis under partial loading conditions indicates that detrimental bending develops in the upper continuous members, particularly when the lower reversely curved members are not present. However, the arch can be stiffened with additional members, such as the reversely curved members in the Upper Pacific Mills Bridge. If only one-half of the span were loaded, the portion of the arch over the unloaded section is loaded eccentrically and would buckle upward, unless some kind of counter is provided to resist this tendency. Analyses of the counterarches indicates that their presence reduces the bending moments present in the upper chords appreciably (by about one-fourth). Shapes of stiffeners other than the reversed curve, however, would probably yield similar results. Lateral stability was provided by inverted rigid frames using transverse triangular beam sections and paired rod suspenders. Although these devices were not mentioned as part of Moseley's original patent, they are important to the viable functioning of the bridge under heavy loading conditions.

#### REHABILITATION

In the summer of 1989 the bridge's wooden understructure partially collapsed, causing the eastern arch to buckle. The owner of the bridge, Atlantic Enterprises, was instructed by the city's engineering department to either repair the structure or replace it with a new bridge. Atlantic Enterprises, being the landlord to many companies on the island, was under lease obligations to provide pedestrian access across the canal and had decided to replace the bridge.

On July 9, 1989, Francis Griggs, a civil engineering professor at Merrimack College made a site visit and discovered that the bridge's wooden



deck was being removed following the collapse. The next day he talked to the City Engineer, Santo Nicolosi, to find out what the plans were for the structure. Nicolosi referred him to representatives from Atlantic Enterprises, who told him of the company's plans to replace the bridge. Griggs asked if he could have the bridge, as he hoped to rehabilitate it and return it to its former use. Atlantic Enterprises agreed, with the proviso that the move would not cost them anything. The contractor, Grasso Construction Company, was planning to cut the bridge up and dispose of it, but Griggs knew Vincent Grasso, a former student of his, and convinced him to remove the bridge as carefully as possible and transport it to the campus of Merrimack College. On July 15 the arches were lifted from their abutments and transported to the campus.

The American Society of Civil Engineers and its student chapter program encourages students to plan and carry out service projects in their local communities. Professor Criggs talked with the officers of the ASCE student chapter, the chairman of the Civil Engineering Department, and the President of Merrimack College, who all agreed that the rehabilitation of the Upper Pacific Mills Bridge should be a student project.

Prior to their actual work on the bridge, the students made measured drawings via CAD (computer-aided drafting), and did structural analysis of its various parts. While their analysis indicated that the counterarches performed no useful function, other analyses have indicated that these arches actually reduce the upper chord's tendency to bend under asymmetrical loading conditions.<sup>6</sup> The Upper Pacific Mills Bridge is very similar to Moseley's patented design, with a few minor exceptions. For instance, the patent states that the vertical straps are riveted to the counterarches, but in the case of the Upper Pacific Mills Bridge, the vertical straps pass between the two angles of the counterarch, and are not riveted to it. Analysis indicated that riveting or not riveting the straps to the counterarches was inconsequential to the strength of the structure.

During the fall, winter and spring, the students removed the deteriorated end portions of the arches and all of the rusted suspension strap connections. Templates were made for new ends of each arch, and the new metal was cut and bent to conform. Examination of the bridge revealed that the bottom tension chord had corroded badly where it came out from underneath the base plate and at several positions corresponding to the panel points. To reinforce this member, a 2"x $\frac{1}{2}$ " steel strap was welded to the bottom of the strap throughout its length. Approximately two-thirds of the ninety-four suspension straps could be reused; the others were replaced with new steel straps.

The two arches were placed on temporary supports early in November and rehabilitation began in earnest. The student team attempted to be as true to the original design and materials as time and money would allow. After searching a wide area for  $\frac{1}{4}$ " wrought-iron plate and finding none, the student-engineers decided to use a steel alternative for the deteriorated sections; welding was used in a few cases where it would not be visible; and, when a riveter could not be located, bolts were used to replace the rivets that had to be removed. Professor Criggs estimates that following the rehabilitation approximately 90 percent of the bridge fabric is original wrought iron.

It is hoped that following the rehabilitation the bridge will be put

UPPER PACIFIC MILLS BRIDGE  
HAER No. MA-72  
(page 8)

back in place across the North Canal at Lawrence, near the location that it occupied for over 125 years. Professor Griggs and his colleagues are currently negotiating with the Lowell Heritage State Park and adjacent landowners to find a site for the bridge.

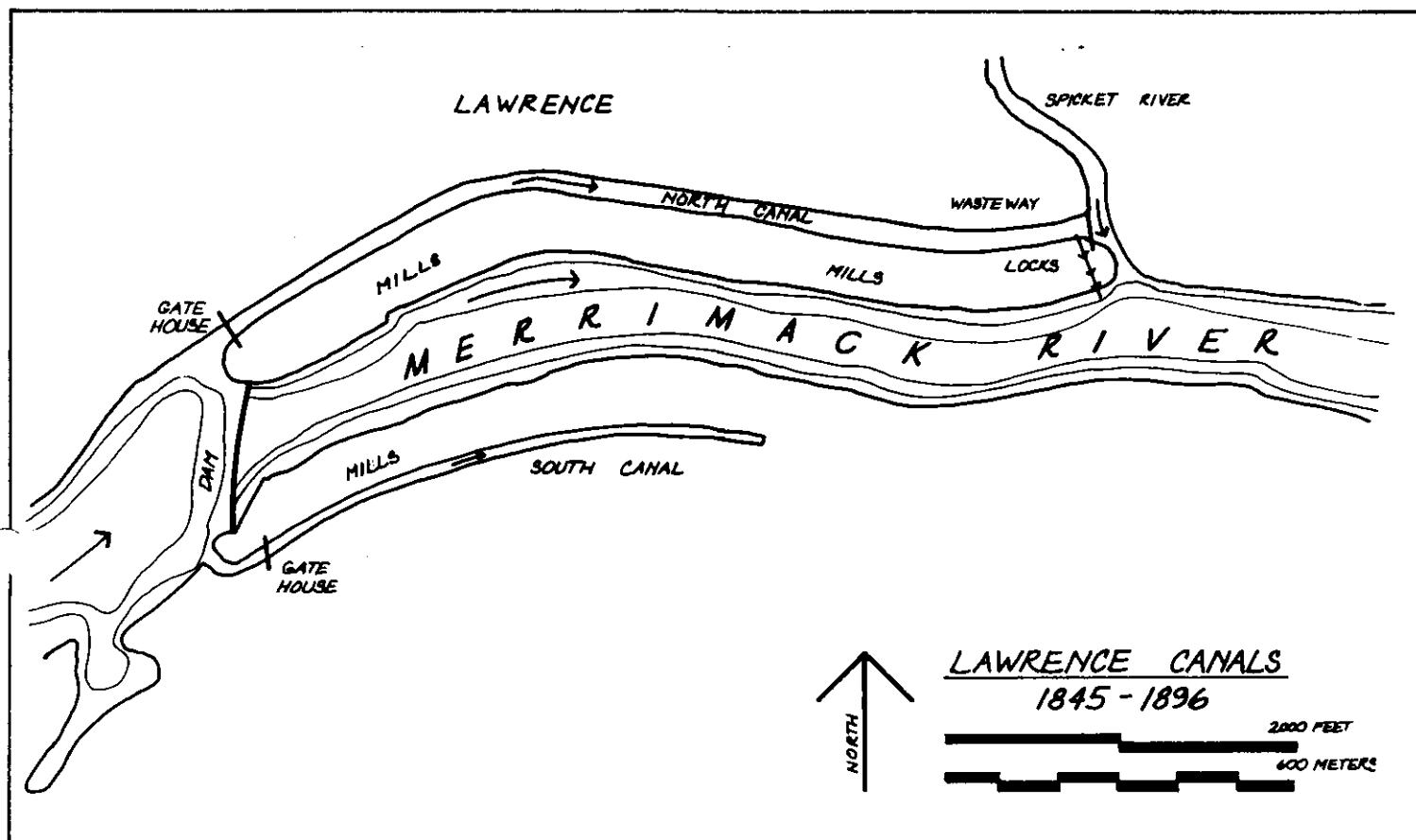


Figure 1. Map of Power Canal System at Lawrence, Massachusetts, 1845-1896  
(U.S. Census, 1880, vol. XVI)

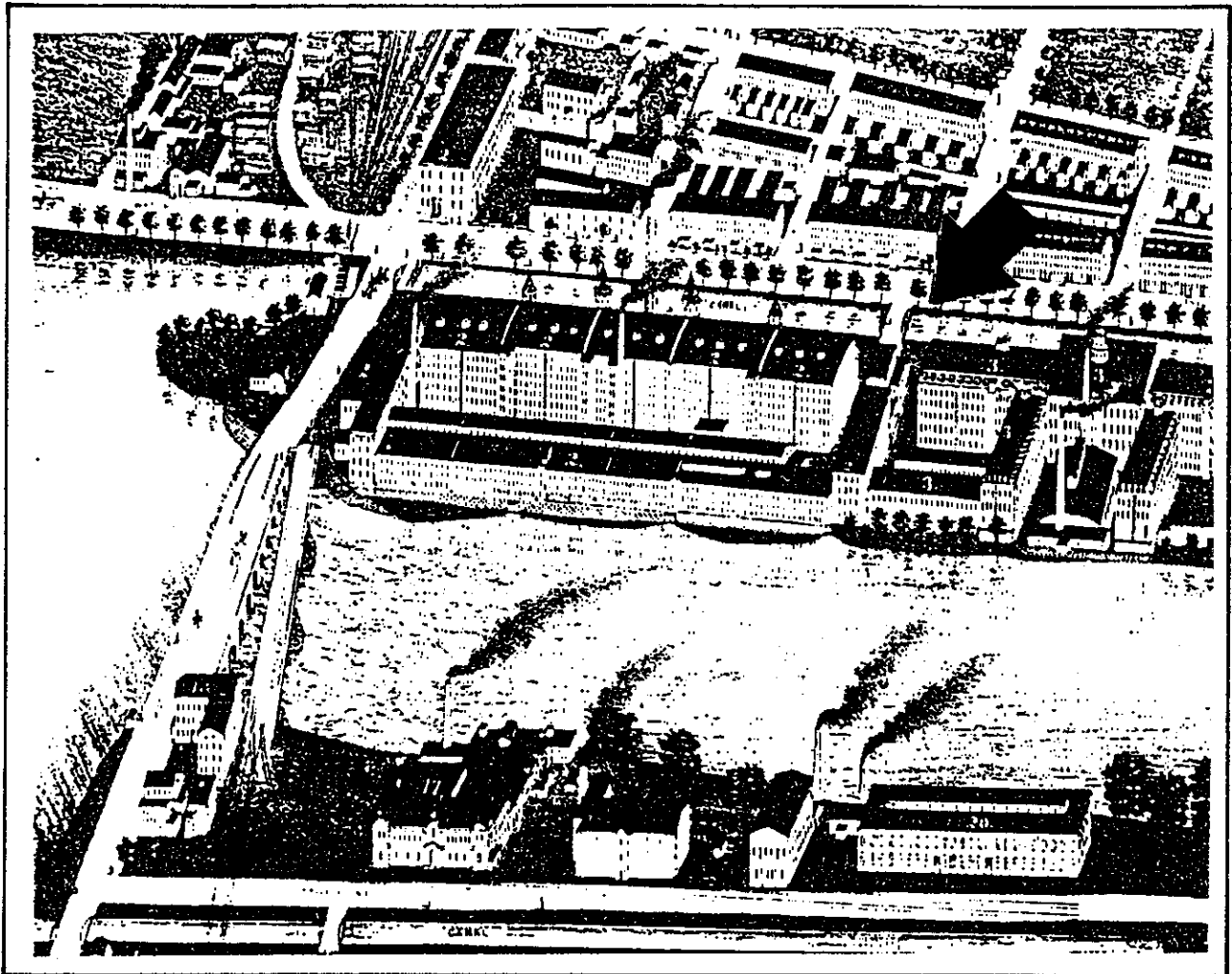
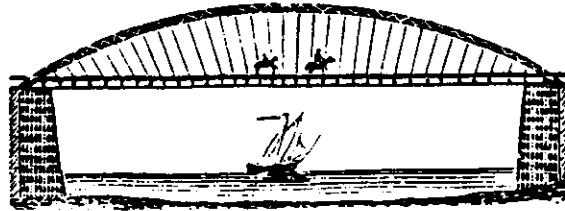


Figure 2. Bird's-eye view of mills at Lawrence,  
showing location of Upper Pacific Mills Bridge



Figure 3. The Upper Pacific Mills Bridge in original location

## MOSELEY'S TUBULAR WROUGHT IRON



### ARCH BRIDGES AND ROOFS.

**THESE BRIDGES AND ROOFS HAVE** now been fully tested in this vicinity, and it is universally conceded that they can not be excelled. The Roofs, are wholly of Wrought Iron, or mixture of Wood and Iron; Sheetting always Iron.

The bridges are wholly Wrought Iron except the floor, which is wood, like the floors of ordinary Bridges.

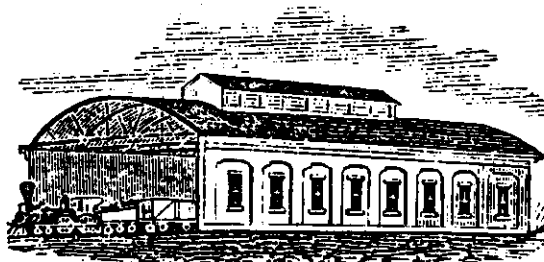
We are prepared to make these structures in any quantities, at prices about as follows:

Railroad Bridges, 50 feet span, 8,000 lbs., \$17 50 per foot lineal.

Common Road or Turnpike, 50 feet span, 2600 lbs. \$5 75 per foot lineal.

Roofs, all iron, 50 feet width of building. \$25 per 100 square feet, part wood and part iron, from \$12 to \$20 per square.

Increase of span of bridges, or width of buildings makes an increase of price, but the increase in price is no more than the increase of wooden structures.



We can furnish iron of every size to work into Bridges and Roofs, and Railroads or other companies buying the right to use them and the iron of us, can make their own structures, one third less than the above prices. Our structures weigh only from 1-4 to 1-10 that of wood; difference in freight in a long distance buys our work. In a few days we will have at our factory, 497 West Third Street, in this city, four different specimens of our Roofs, where the public can inspect them to their satisfaction. We beg them to give us a call, as all our work is warranted, and we ask no pay on ordinary jobs until the work is done and approved, payments being secured on contracting.

Office, No. 66 West Third street, Cincinnati, O.  
may 13.

1859

MOSELEY & CO.

Figure 4. Advertisement for Moseley's Tubular Wrought-Iron Arch Bridge, 1859  
(Railroad Record, May 1859, p.288)

Moseley's Tubular Wrought-Iron Arch Bridge,  
FOR RAILROADS AND HIGHWAYS.

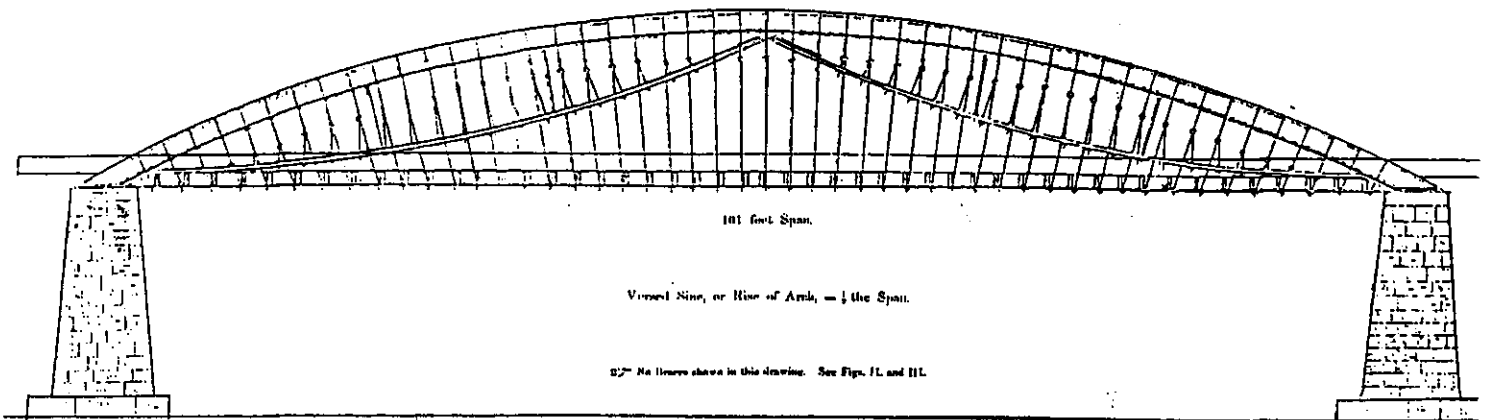
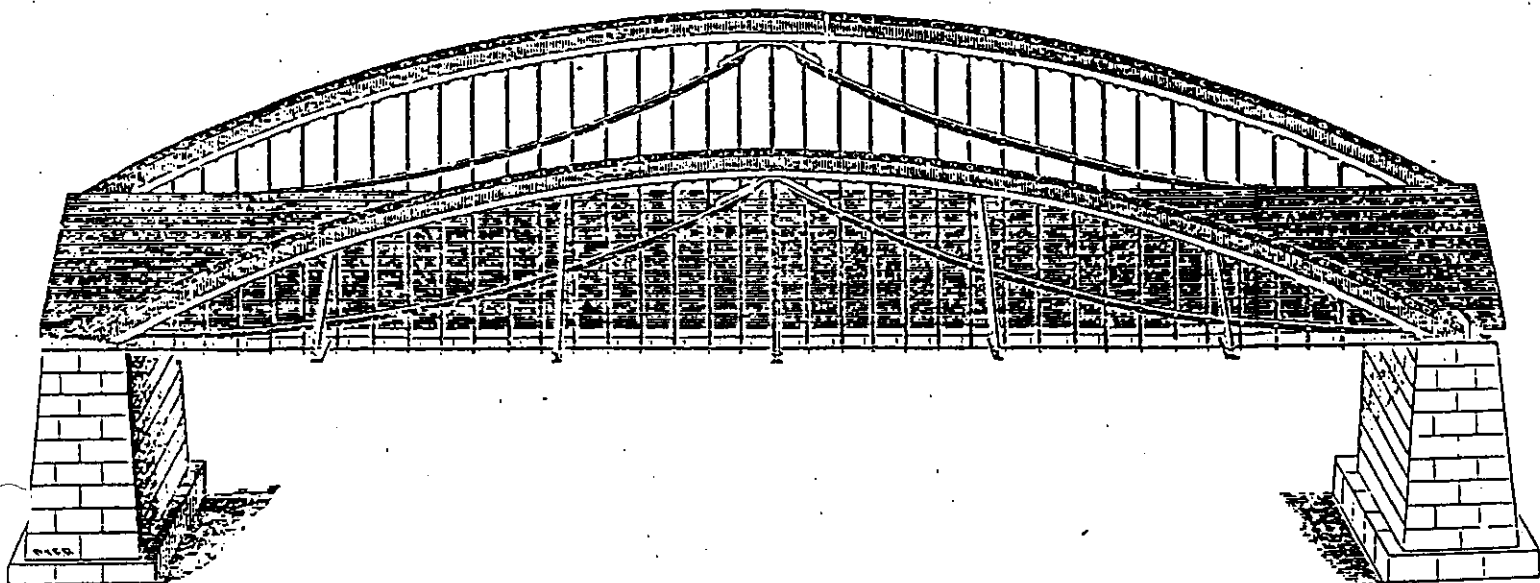


Figure 5. Illustrations of Moseley's Tubular Wrought-Iron Arch Bridge  
(Iron Bridges, Roofs, Buildings, & c.  
Manufactured by the Moseley Iron Building Works, promotional brochures)



UPPER PACIFIC MILLS BRIDGE  
HAER No. MA-72  
(page 14)

APPENDIX:  
MOSELEY PATENTS



# UNITED STATES PATENT OFFICE.

THOMAS W. H. MOSELEY, OF COVINGTON, KENTUCKY.

## BRIDGE.

Specification of Letters Patent No. 16,572, dated February 3, 1857.

### To all whom it may concern:

Be it known that I, THOS. W. H. MOSELEY, of Covington, in the county of Kenton and State of Kentucky, have invented an Improvement in Bridges, and that the following is a full, clear, and exact description of the principle or character which distinguishes it from all other things before known and of the usual manner of making, modifying, and using the same, reference being had to the accompanying drawings, of which—

Figure 1 represents a side elevation of part of one of the arches. Fig. 2 a cross section showing the form transversely of the arches. Fig. 3 is a plan or top view of one half of one of the arches. Fig. 4 a detached view showing the mode of constructing the arches and, Fig. 5 represents the diagonal cross braces which extend from arch to arch.

My invention consists in certain improvements in iron bridges hereinafter described whereby I attain lightness, strength, durability, and economy beyond any iron structure heretofore used for such purposes.

The arches A, A, of my bridge are of a compound character and are built up of wrought plate iron in such manner as to give to the whole arch transversely the form and strength of an arch, and to admit of very long spans without excessive weight, presenting at once the combined features of extraordinary strength and lightness. Hollow arches for such purposes have been essayed before but of such form, application and material as to be objectionable on the grounds of expense, great weight and derangement from expansion and contraction by changes of temperature.

A transverse section of my compound arch as shown in Fig. 2, exhibits an arch in the form of an isosceles triangle the base B of which is the chord of the arch. This form is best adapted to strength, lightness and economy of construction and is in fact the only form with the least weight that can be given to a hollow iron arch for such purpose which is not liable to buckle.

The plates P, P, P, P, Fig. 4 composing the arch are so arranged in its construction as to break joints for the purpose of strength; and for additional strength to the triangular arch, I insert a vertical plate R bolted to the base plate B and secured to plates P, P, P, P, by rivets thus uniting the

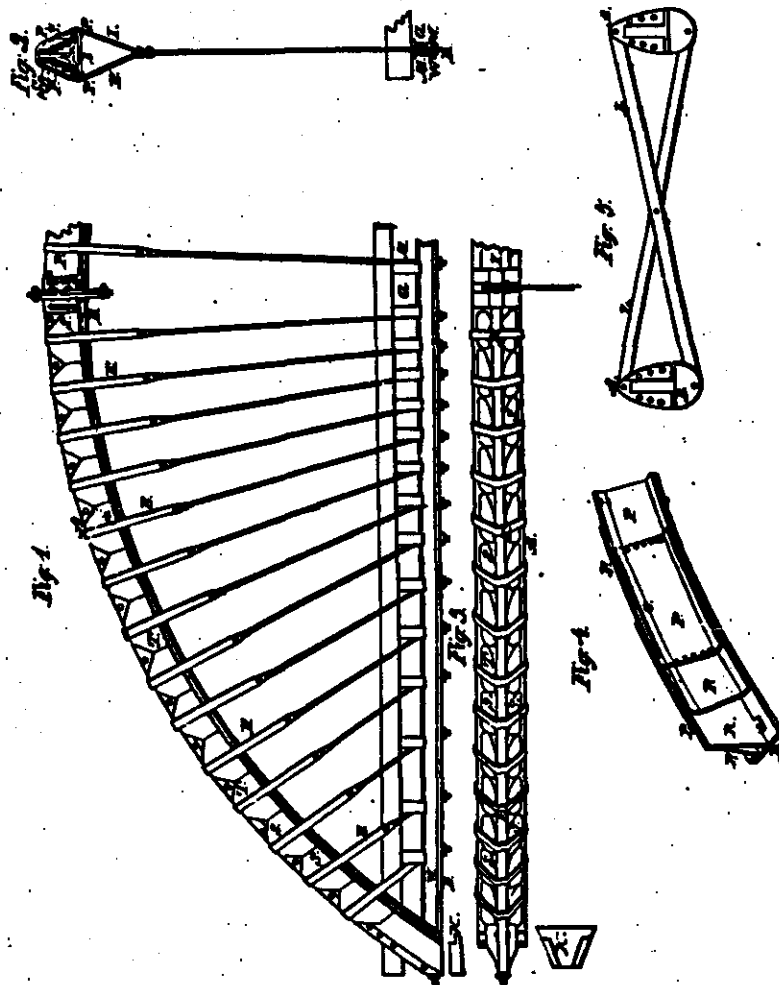
plates P, R, and B in the most advantageous manner for producing a light and rigid structure, for its own support and the bridge below. Under a strain in any direction which may come upon this compound arch there is less risk of buckling of either of the plates than in other structures for such purpose. In order however to give the utmost strength to the compound arch and preventing all risk of buckling of the plates I insert loose pieces S, S, which I term saddles. These pieces rest upon the plates B, and also bear upon the plates P, P, and also support each other by their edges which come into contact as seen at T. These pieces are not secured to either plate but are inserted loosely and their upper edges receive a part of the pressure of the stirrups E, E, of the suspension rods F F. The chain of saddles on either side of the compound arch thus forms an independent arch and the effect of each individual saddle is to give tension to the plates P, P, where under great pressure in consequence of the pressure of the saddle upon the base plate B and thus prevent the buckling of the plates and with this last increment of strength and support, it is obvious that the arch can give way to extreme pressure only by the actual rupture of the metal of plates P, B, and R. The exterior face of the saddle is formed for lightness and strength, the superfluous metal being removed from those parts subjected to the least strain. The suspension rods are radial or nearly so to the curvature of the arch and therefore all of them inclined to the versed sine of the arch. The flooring of the bridge rests upon the chord M of the arch which is secured to the feet of the arch and supported by the suspension plate D. The suspension rods pass between the two plates G, G, which compose the chord M and the rods are then bolted to the suspension plate D. The suspension plate is not fastened to the chord M and the effect of this in conjunction with the radial suspension rod is, in case of great weight upon any part of the bridge to throw the strain upon the whole span at once.

It will be seen that on no part of the bridge is any weight or pressure under the point of suspension of that part and that every load draws upon the whole arch in consequence of the sliding movement of the suspension plate under the chord M. The chord M is kept in position laterally upon

*T. M. H. Moseley*  
*Truss Bridge*

*NR 10,572*

*Patented Feb. 3, 1897*



2

16,572

plate D by flanges W, W on this plate. The feet of the arch rest upon corrugated shoes K, K, for the twofold purpose of producing friction upon the abutments and of working their way by gradual abrasion into the material of the abutments and securing a firm hold. The two arches A, A, are held together at top by diagonal braces L L.

What I claim as my improvements is—

- 10 1. The compound arch constructed substantially as herein set forth.
2. I claim the saddle pieces in combina-

tion with the stirrups and said compound arch.

3. I claim the sliding suspension plate in combination with the chord M and radial suspension rods as set forth.

4. I claim the corrugated shoes K K as set forth.

THOMAS W. H. NOSELEY.

Witnesses:

CHAR. G. PAGE,  
K. T. CAMPBELL.

# UNITED STATES PATENT OFFICE.

THOMAS W. H. MOSELEY, OF BOSTON, MASSACHUSETTS.

## IMPROVEMENT IN BRIDGES.

Specification forming part of Letters Patent No. 59,054, dated October 23, 1886.

*To all whom it may concern:*

Be it known that I, THOMAS W. H. MOSELEY, of Boston, in the county of Suffolk and State of Massachusetts, have invented a new and useful Improvement in Wrought-Iron Trusses for Bridges; and I do hereby declare the same to be fully described in the following specification and represented in the accompanying drawings, of which—

Figure 1 is a perspective view of a bridge-span made with two of my improved trusses. Fig. 2 is a transverse section of it. Fig. 3 is a perspective representation of one end of the truss, with its shoe and the adjusting-rods and nuts applied thereto. Fig. 4 is another end view of the truss, without the flange-plates.

In the drawings, A denotes a girder, to be made of plate-iron, and to have the form of the segment of a circle or an ellipse, or an approximation thereto. A long strip of metal, B, which I term the "chord," is laid along the chord of the said girder, and connected thereto by bolts *b b b* going through the two, and a series of hangers, *a a a*, arranged against the inner face of the girder and projecting below it. In the formation of a bridge these hangers go down through the series of floor-timbers *r c c*, which connect the trusses of the span, and serve to support the flooring-planks *d*, the floor-timbers being held in connection with the hangers by screws and nuts applied to the lower ends of such hangers, they being shown at *r r* in Fig. 2.

To projecting parts *f f*, at the ends of the arched-plate girder A, rectangular strengthening-plates *g g* are riveted, the said plates being placed flatwise against the girder-plate. There is also riveted to each side of the arched girder and along its arc an angle-iron flange, C,

shaped in cross-section as represented in Fig. 2, the rivets for hobbling the flanges to the girder being shown at *i i* in Figs. 2 and 4.

At each toe or end of the truss is a shoe, D, consisting of a sheet of plate-iron bent at a right angle. These shoes rest on the abutments or piers E E, and each is secured to the truss by two bolts, *k k*, which are connected to the truss, and extend from it in opposite directions, at acute angles with it, and go through the vertical part of the shoe and terminate in screws, on which nuts *l l* are screwed. These bolts, with their screws and nuts, besides serving to secure the shoes to the truss, answer another purpose—viz., as means of adjusting the truss, or springing or drawing it laterally (more or less) in either direction, as circumstances may require.

A truss made of thin plate-iron, and in manner as above described, has been found to possess great strength and stability, and it can be constructed at very little expense in comparison to what is frequently expended for trusses of a like span.

I claim as my invention.—

1. The improved truss, as composed of the arched plate A, the chord B, and the flanges C C, or the same and the end strengthening-plates *g g*.

2. The combination of the shoes D D, and their adjusting screw-bolts *k k* and nuts *l l*, with the truss made of the arched plate A, the chord B, and the flanges C C, or the same and the strengthening-plates *g g*, the whole being arranged substantially as described.

THOS. W. H. MOSELEY.

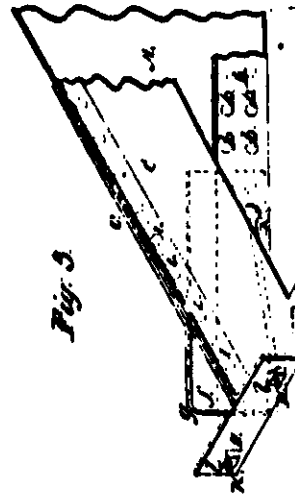
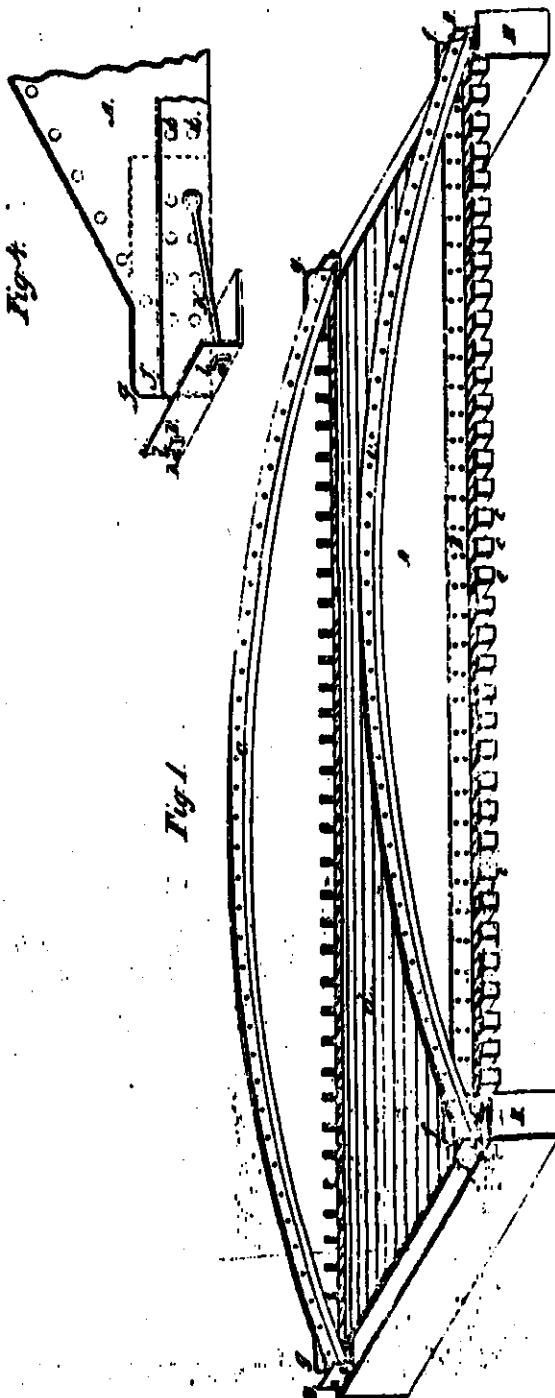
Witnesses:

R. H. EDDY,  
F. P. HALE, Jr.

*T. W. H. Moseley*  
*Truss Bridge.*

*No 59,054.*

*Patented Oct. 23, 1906*



*Witness*  
*R. H. Lacy*  
*By P. H. Lacy*

*Inventor*  
*Thos. W. H. Moseley*

# UNITED STATES PATENT OFFICE.

THOMAS W. II. MOSELEY, OF BOSTON, MASSACHUSETTS.

## IMPROVEMENT IN TUBULAR-ARCH BRIDGES.

Specification forming part of Letters Patent No. 103,705, dated May 31, 1870.

I, THOMAS W. II. MOSELEY, of Boston, in the State of Massachusetts, have invented certain new and useful Improvements in Bridges, which invention is described as follows:

### *Nature and Objects of the Invention.*

The subject of my invention is a tubular-arch bridge. The arch is quadrangular in its transverse section, being constructed of four plates, connected by flanges to each other and to a diaphragm-plate, which is interposed in a vertical plane centrally between the two sides or halves of the arch. The upper edges of these diaphragm-plates are curved, to correspond with the contour of the top of the arch. Their lower edges are straight, or nearly so, and are nearly coincident with the chords of arcs extending from beneath the apex of the arch to its toe at each end. The diaphragm-plates impart great strength, especially to the hips of the arch, by affording a greater depth of girder at those points.

My invention further consists in employing the said diaphragm-plates for the attachment of the upper ends of the suspension-rods, to the lower ends of which the chord-bars and floor-beams are secured.

The third and fourth parts of my invention relate to devices for connecting the arch and its chord-bars, and sustaining the thrust of the one and the tensile strain of the other.

The fifth part of the invention relates to cross or diagonal bracing, employed to impart additional stiffness and strength to the hips of the arch.

### *Description of the Accompanying Drawing.*

Figure 1 is a side elevation of a bridge, illustrating my invention. Fig. 2 is a side elevation of one end of the same on a larger scale. Fig. 3 represents a vertical transverse section of one side thereof.

Like letters of reference refer to corresponding parts in all the views.

### *General Description.*

The main supporting parts of my bridge consist of two or more metallic tubular arches, A, of which one only is here shown. The arch is formed of plates of wrought-iron from one-tenth of an inch to an inch or more in thickness, and from three inches to six feet or more

in width, as the length or span of the bridge or the service it is to perform may require. The plates of which the arch is made are sheared in circular arcs of radii to suit the span desired. The longitudinal flanges *a a*, through which the plates are riveted together, are formed on their edges, varying in width as the plates vary—say, from one inch to eight inches or more—and in angle to suit the intended form of the tube in its transverse section. This section is preferably rectangular, as shown in Fig. 3, or diamond-shaped, with the acute angles up and down and the obtuse angles at the sides, so as to bring the major axis in a vertical plane. For a tube of square section the flanges are bent at angles of forty-five degrees, and the angles are correspondingly varied for other forms of sections, so that the planes of the flanges in the finished tubes will bisect the angles formed by the junction of the plates.

The structure thus far described consists of a curved tube of quadrangular section. In application the edge or angle *a'*, having a longitudinal convexity, is placed uppermost, and that which is concave at bottom; and in order to produce an arch of great power and strength, I apply, vertically and longitudinally, between the halves of the arched tube a wrought-iron plate, B, which may be of equal thickness with the side plates of the tube, and is secured between the upper flanges, and also between the lower flanges, by through-rivets.

The plate B thus divides the tube A from angle to angle, forming two prisms or triangles, and producing the strongest form into which iron can be put for such a purpose. This division-plate B, I term a "diaphragm." Its upper edge is curved to conform to the concave or top flanges of the arch-plates; but its lower edge, instead of conforming to the lower concave edge of the arch-plates, is left straight.

The plate B is thus adapted to serve three distinct purposes: First, it forms a chord to halt the arch; second, it affords additional depth of girder at the hips or haunches of the arch, thereby imparting greatly increased strength and stiffness at these points, which, in all arches, are the most frail and flexible parts; third, it is employed for the attachment of the vertical bars, which sustain the chord.

bars and the floor-beams of the bridge, and of the diagonal or cross bracing, which is secured to the said plate above and to the main chords below, as hereinafter explained.

Two of the above-described curved tubes A, with their crescent-shaped diaphragms B, are placed together, end to end, as represented in Fig. 1, to form each arch of the bridge.

The vertical suspension-bars D vary in size according to requirement, say from two inches wide and a quarter of an inch thick up to double that size, or more. They are attached, about two feet apart, in the lower part of the diaphragm B, and extend downward between the two chord-bars E E, to which they may be united by through bolts or rivets.

In some cases I weld to each suspension-bar a round rod, F, which is passed through each of the floor-beams G, and is provided at its lower end with a screw-thread to receive a nut, H, which supports a washer, I, upon which the floor-beams rest. In other cases I employ stirrups J, Fig. 1, constructed in U form, of flat bar-iron. The legs of these stirrups enclose the floor-beams, and project upward between the chord-bars E E, to which they are secured by bolts or rivets. The floor-beams rest with a uniform and level bearing on saddles K, which fill the curves of the stirrups.

My mode of making a union of the chords with the arches, at the feet of the latter, is as follows: Each diaphragm-plate B is united at its lower or outer end to a foot-plate, C, which forms a continuation of the diaphragm B, extending between the two sides of the arch to the toe or extremity thereof, and down to the bottom of the arch and the lower edges of the chord-bars. A wrought-iron plate, L, called the "shoe," generally one quarter thicker than the side or diaphragm plate, lies in a horizontal position under the foot of the arch. This shoe is generally made in width equal to one-fourth the vertical height of the arch at its apex, and in length equal to twice or more the greatest diameter of the toe of the arch. Such length is necessary to allow room for rivets, by which it is united to the horizontal stems of the angular chord-bars E, a sufficiency of rivets being used to equal the horizontal stem of the chord-bars E in substance and strength.

To the sides of the arches, where they come in contact with the shoe L, are riveted smaller angle-bars, M, the horizontal stems of which are riveted to the shoes, and similar angle-bars, N, connect the upturned end L' of the shoe to the toe of the arch.

The upright stems of the angle-bars are united to the foot-plate C by like rivets, as shown at c, of strength equal to that of the vertical stems of the chord-bars. The diaphragm-plate B is further united to the shoe at its lower end by battens and rivets on each side of the joints, as shown at b. All the joints of the diaphragm-plates, both within the arch-tubes and on the outside thereof, are formed by battens and rivets b, in similar manner.

To impart additional stiffness to the hips of the arch, I apply, when necessary, diagonal vertical braces O O, of T-iron, crossed, with their straight faces riveted together, their upper ends being riveted to the diaphragm-plates B, and their lower ends secured between the chord-bars E.

#### Claims.

The following is claimed as new:

1. The arch-tube A, of quadrangular section, constructed of flanged plates, combined with a diaphragm-plate, B, substantially as described.
2. The diaphragm-plates B and suspension-bars D, combined with each other, and with the arch A and chord-bars E, substantially as set forth.
3. The diaphragm-plate B, foot-plate C, and shoe L, when connected and arranged to act as described.
4. The combination and arrangement of the arch A, foot-plate C, shoe L, and chord-bars E E, substantially as and for the purposes specified.
5. The diagonal braces O O, constructed and applied substantially as herein stated, in connection with the arch A, plate B, and chord-bars E.

THOS. W. H. MOSELEY.

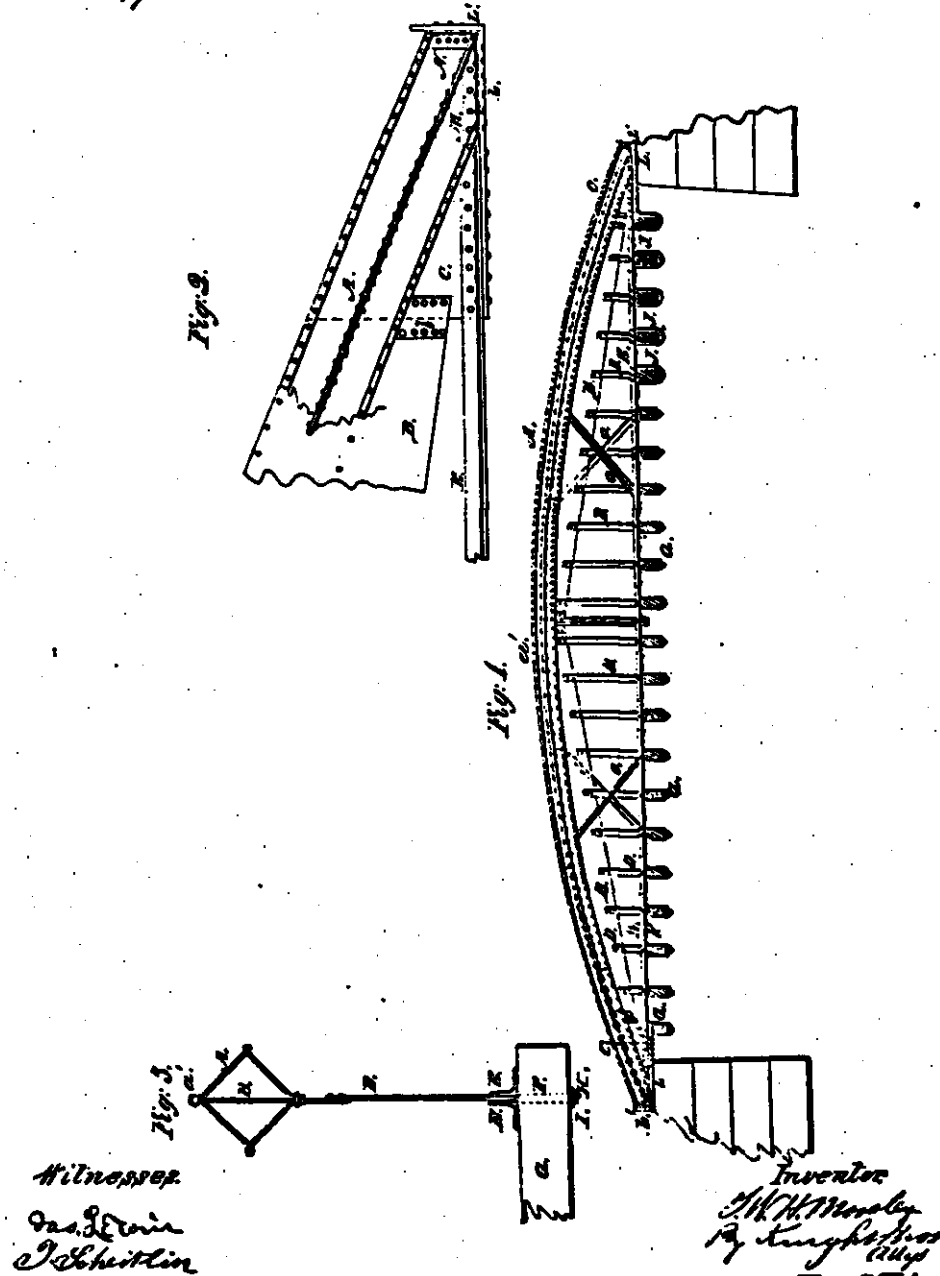
Witnesses:

WM. H. BRERETON, Jr.,  
OCTAVIUS KNIGHT.

*T. W. H. Moseley*  
*Truss Bridge*

*No 103,765.*

*Patented May 31, 1870.*





# UNITED STATES PATENT OFFICE

THOMAS W. H. MOSELEY, OF BOSTON, MASSACHUSETTS.

## IMPROVEMENT IN BRIDGES.

Specification forming part of Letters Patent No. 108,855, dated August 30, 1870.

*To all whom it may concern:*

Be it known that I, THOMAS W. H. MOSELEY, of Boston, in the county of Suffolk and State of Massachusetts, have invented an Improved Bridge, of which the following is a specification:

My invention is a combination of the mechanical elements or features which occur singly or in various minor combinations in bridges. These elements, as they may be termed, are the king-post, truss, arch, and girder, the object being to avail the use of all in a structure, to which each shall impart its distinguishing characteristics and valuable quality.

In the accompanying drawing, Figure 1 is a side elevation of a bridge constructed after my plan, and including about three-quarters of the span. Fig. 2 is a sectional view, on an enlarged scale, of this bridge, on the dotted line *a b*, Fig. 1. Fig. 3 is a view, on a scale larger than that of Fig. 1, of one of the ends of the structure, which form the side of a bridge. Fig. 4 is a perspective view of that portion of the structure in the vicinity of the foot of the king-post.

The structure which forms one side of the bridge consists, in the main, of *A A*, a pair of inclined beams, which meet at the middle of the span, and are stepped against foot-plates *C*, resting on sole-plates *D* on the abutments *E*. (The ends of the bridge are similar, and but one is shown in the principal figure.)

*b b'* is an arch, which is secured to the two beams, and springs from the sole-plates *D* on the respective abutments; *G*, a girder or chord, which unites the foot-plates *C* and sole-plates *D*, and thus sustain the thrust, and act as a chord to the arch; *H*, a king-post, which forms the middle vertical member of the truss, connecting the beams at their junction with the girder or chord at its mid-length; *I*, a tension-rod, connecting the haunches of the arch *b b'* with the foot of the king-post *H*; *K K*, &c., suspension rods from the beams *A A*, to support the girder or chord and the track-sleepers.

I now proceed to describe the parts more in detail.

The beams *A* meet at the crown or pitch, and each consists of a fin, *a*, strengthened and

stiffened by angle-iron *a' a'* on its sides at the upper edge, and riveted thereto. These fin-plates rise at an angle varying from six to twenty-two degrees, as may be needed, and are the equivalents of the beams or braces in a king-post bridge, or the principal rafters in a roof-truss. The foot of the fin-plate rests against the foot-plate *C*, which corresponds in function to a skew-back or thrust-block. The foot-plate rests upon and is secured to a sole-plate of shoe *D*, which also receives the springing of the arch *b b'* and the end of the girder *G*, as will be presently described. The iron fin-plate *a* varies in thickness as the span of the arch and the expected burden may require, say, from one-eighth of an inch to one inch or more in thickness, and in width to make a chord to half the arch *b b'*, and to represent on the back of the latter two tangents, meeting at the haunch.

Unsupported, this fin-plate, even with the stiffening of angle-iron on the upper edge, lacks the lateral rigidity to make it serviceable as a thrust-beam; and this brings me to the description of the arch *b b'*, which is made of upright angle-iron, I-iron, or Z-iron, which is preferably of the form best seen in Figs. 2 and 3.

The plate, as shown, has two flanges, *b b'*, united by a web, *b''*, the flanges being vertical, and the web following the camber of the arch. A pair of such angle-irons is riveted to the ends of the thrust-beams *A A*, one on each side of the latter. The angle-plates forming the arch vary in thickness and width with the span and expected burden of the bridge, being, say, from one-fourth inch to two inches or more in thickness, and from three inches to two feet or more in width. They are riveted through and through on each side of the fin-plate, as shown in Fig. 2. The shoe-plate *D* receives the springing of the arch, and has a turned-up toe, *d*, against which the heel of the arch thrusts.

The girder *G* forms the chord of the arch *b b'*, and also prevents the spreading of the feet of the beams or fin-plates *A A*. Each girder is made of flat-bar, flat-plate, or angle-iron, and preferably of the latter, as clearly seen in Fig. 3, the shaped irons being laid with their vertical flanges back to back, and riveted to-

gether at intervals. At their ends these girders or chords embrace between them the foot-plate U, to which they are securely riveted. The horizontal flanges of these girders or chord-bars are likewise riveted to the sole-plate D, some of the rivets being seen at *g g*, Fig. 3.

I have now described the elements constituting of the inclined beams, the arch, and the girder. The angle plate arch being added to each side of the fin-plates A, keeps the latter in perfect line, and they thus exert their full strength, and each becomes a chord to one-half of the arch, strengthening the latter, especially at its haunches.

H is an iron king-post, preferably formed of two T-bars, *h h*, with their faces together, as seen in Fig. 4. These extend from the beam A above to the girder-plates G beneath, and are made fast to each.

I I are tension-rods, one on each side of this bridge-truss. These are attached at their ends to the ribs of the plates A A, pass obliquely downward to or nearly to the girder G, and take hold of the foot of the king-post, which

is then utilized as a strut in the support of the apex of the compound beam and the crown of the arch, the two being practically coincident as to position. This straining-rod has notch, cut, or gib, to prevent its slipping when the load or burden is thrown on the haunch of the arch.

The suspension-rods K are similar to those in other bridges, and depend from the fin-plate, to support the girders or chords G and the sleepers of the road-bed, as shown at Fig. 2.

Cross or lattice bars may be used between the fin-plates A A and the chord G, in connection with, independent of, or to the exclusion of the suspension-rods K.

What I claim as new is—

The combination, in one bridge-truss, of the following elements: The beams or fin-plates A A, the arch *b b'*, the girder or chord G, king-post H, and tension-rods I I, arranged as described, or in any equivalent manner.

THOS. W. H. MOSELEY.

Witnesses:

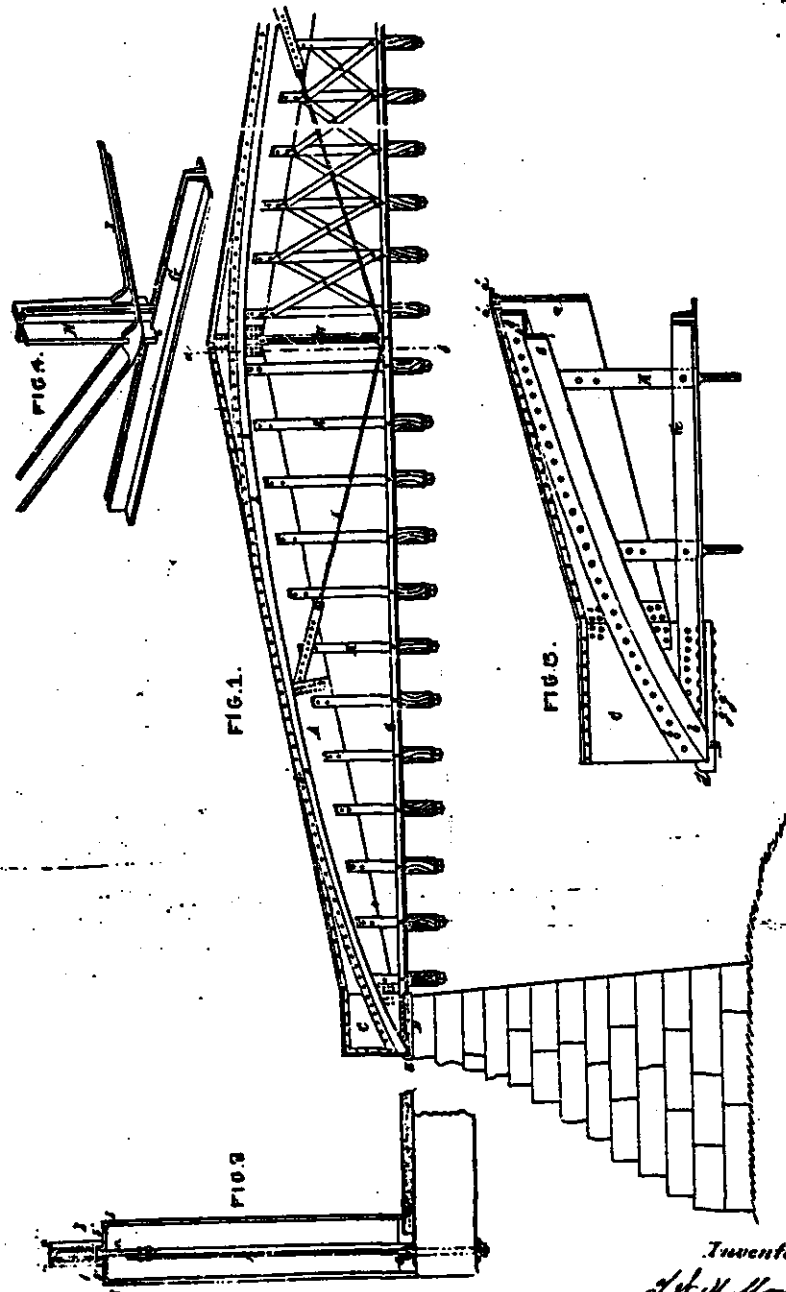
JOHN MULFORD,  
A. P. HOUGH.

*T. W. H. Moseley,*

*Truss Bridge.*

*No. 100,855.*

*Patented Aug. 30, 1892.*



Witnesses;  
*Geo. L. Currier*  
*Edward Wright*

Inventor;  
*T. W. H. Moseley*  
*By Knight & Moseley*

ENDNOTES

1. Thomas W.H. Moseley, Iron: New Enterprise in its Manufacture and Application to Building (Boston, 1863), 11.
- 2.
3. "Thomas W.H. Moseley," obituary in The Boston Journal (March 16, 1880), 4.
4. All four patents are included in the appendix, even though three of them were obtained after the construction date attributed to the Upper Pacific Mills Bridge.
5. Iron Bridges, Roofs, Buildings, & c. Manufactured by the Moseley Iron Building Works, promotional brochure (Boston, 1870).
6. Daniel L. Schodek, Unpublished manuscript containing engineering analysis of several historic bridges in Massachusetts (Harvard University Graduate School of Design, 1991).

REFERENCES

Barlow Insurance Survey Maps. Merrimack Valley Textile Museum.

Brock, F.B. "An Illustrated Historical Description of All Expired Patents on Truss Bridges, Which Under the Law Are Now Public Property and Free to be Used by Anyone," Engineering News and American Contract Journal (March 10, 1883), 120.

Iron Bridges, Roofs, Buildings & c. Manufactured by the Moseley Iron Building Works, promotional brochure, Boston, 1867 and 1870.

Molloy, Peter M., ed. The Lower Merrimack River Valley: An Inventory of Historic Engineering and Industrial Sites. North Andover, Massachusetts: Merrimack Valley Textile Museum and the Historic American Engineering Record, 1976.

Moseley, Robert B. "Thomas the Engineer and Inventor," Genealogical Notes Concerning the Moseley Family, 1948, typed manuscript located at the Virginia Historical Society, Richmond, Virginia.

Moseley, Thomas W.H. Iron: New Enterprise in its Manufacture and Application to Building. Boston, 1863.

Moseley, Thomas W.H. "U.S. Patent No. 16,572," February 3, 1857.

\_\_\_\_\_. "U.S. Patent No. 59,054," October 23, 1866.

\_\_\_\_\_. "U.S. Patent No. 103,765," May 31, 1870.

\_\_\_\_\_. "U.S. Patent No. 106,866," August 30, 1870.

Simmons, David A. "Bridges and Boilers: Economics in Mid-Nineteenth Century Ohio and the Invention of the Tubular Iron Bridge," unpublished typescript, 1990.

Stone, Orra. Massachusetts Industries. Boston, 1929.

"Thomas W.H. Moseley," obituary in The Boston Journal (March 16, 1880), 4.

"Thomas W.H. Moseley," obituary in The Boston Traveler (March 12, 1880), 3.

Whipple, Squire. Letter to A.P. Boller, in Railroad Gazette (April 19, 1880).